

# Location-Specific SHA

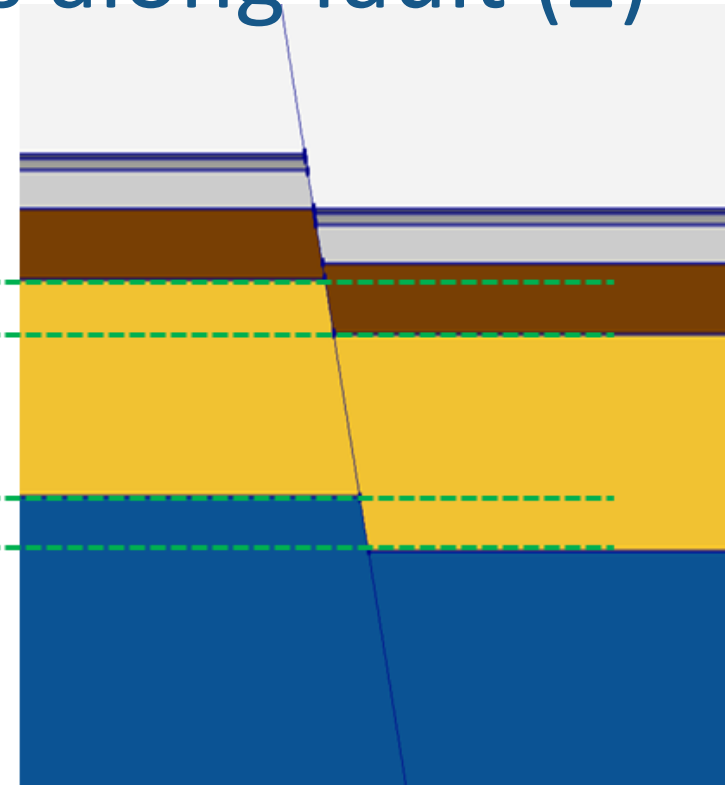
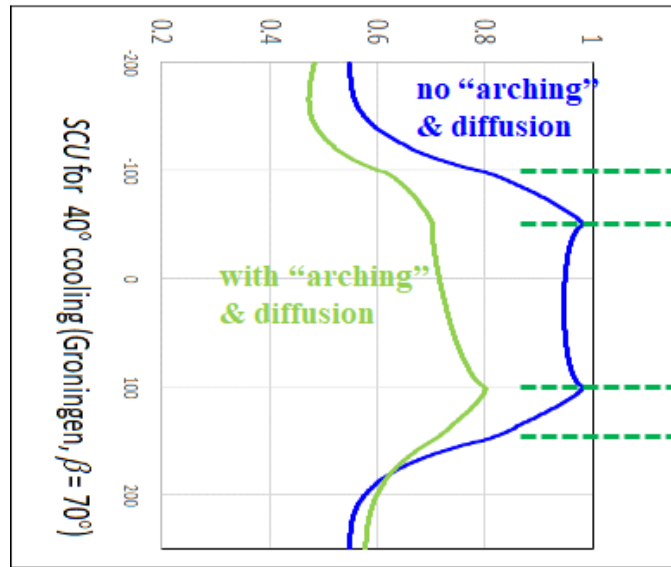
Bleiswijk  
(VDB GT-02-S1)

Project code: 2200122

# Contents

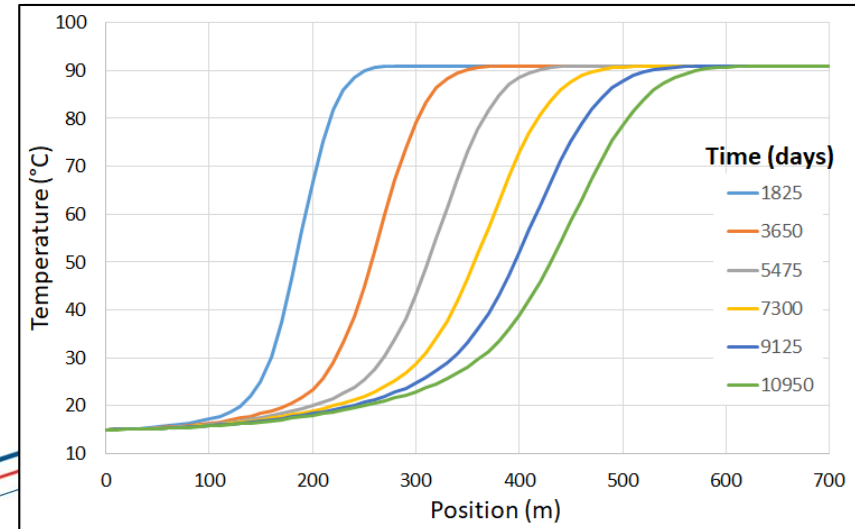
- General Intro & Methodology
- VDB-GT-02-S1: SHA, 40 years
  - Computation of SCU-profile along the fault
  - Monte Carlo simulations to address parameter uncertainties
- Conclusions

# Method of stress analysis along fault (2)

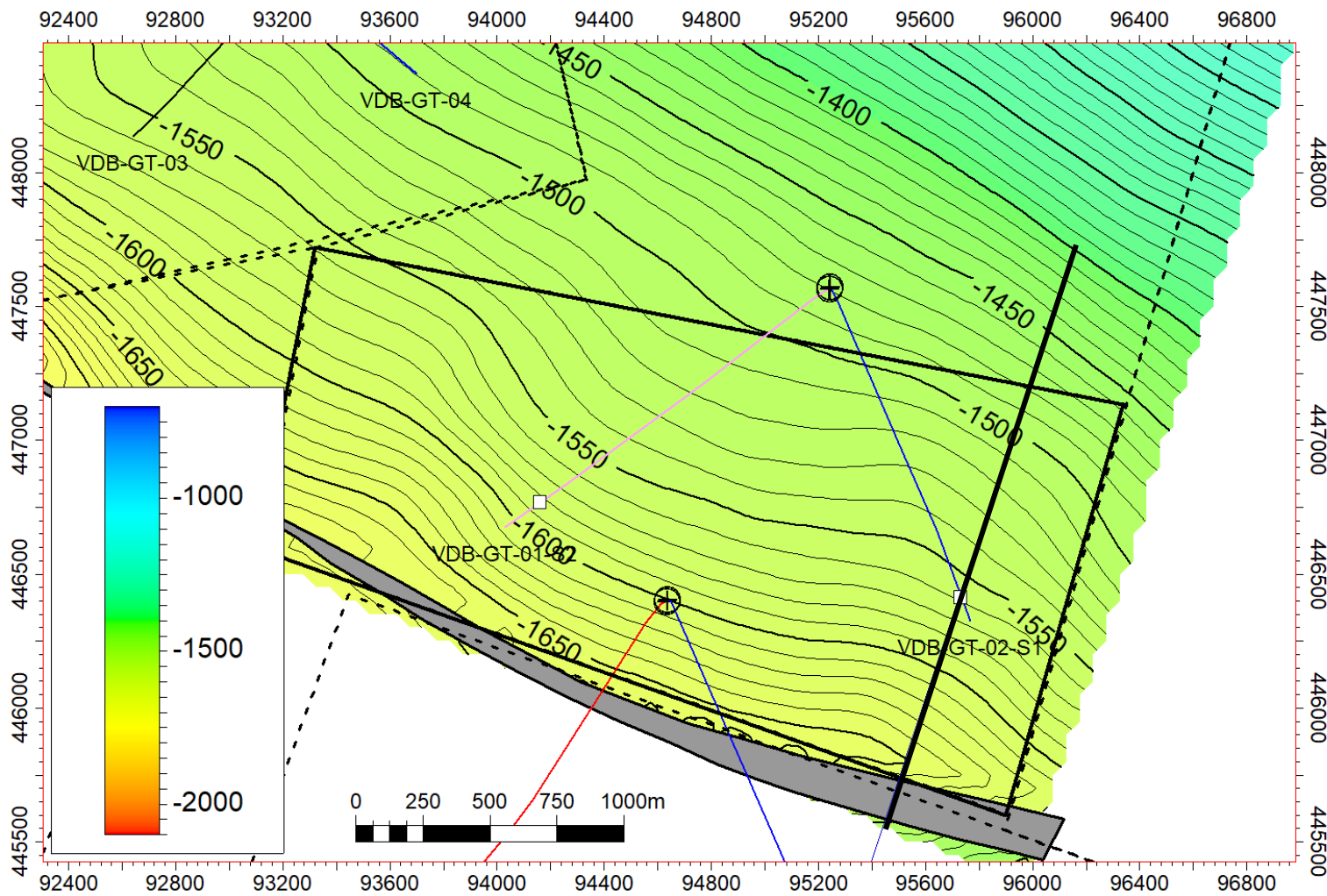


## Reservoir cooling

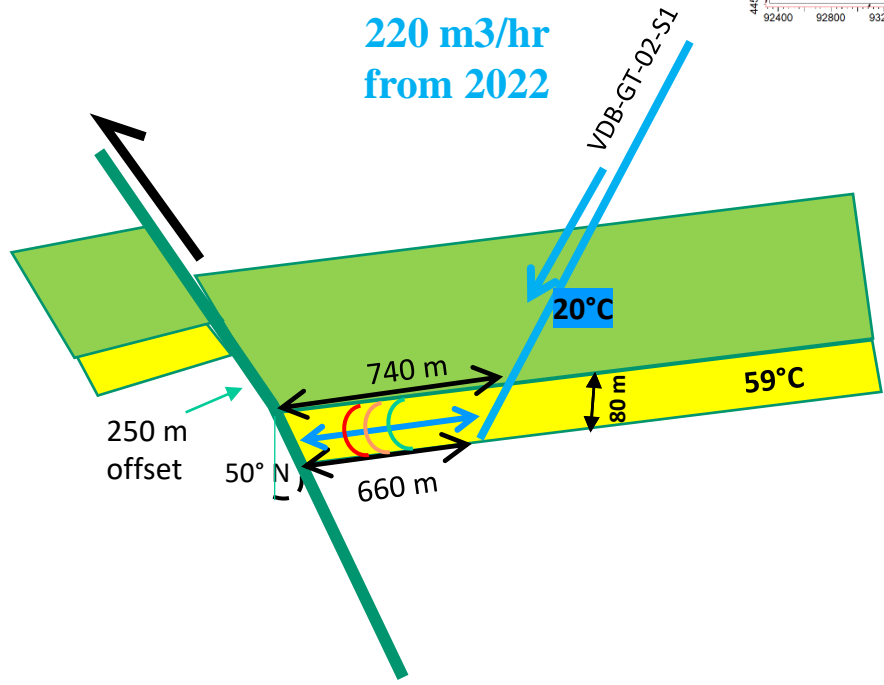
- Thermal diffusion cap & base rock
- Thermal diffusion within reservoir
- Stress concentrations along fault less pronounced
- Limited extent of cooled zone
- Arching reduces stress concentrations along fault
- **Conservative:** assume that fault conducts all injected water to opposite side (i.e. non-sealing fault)



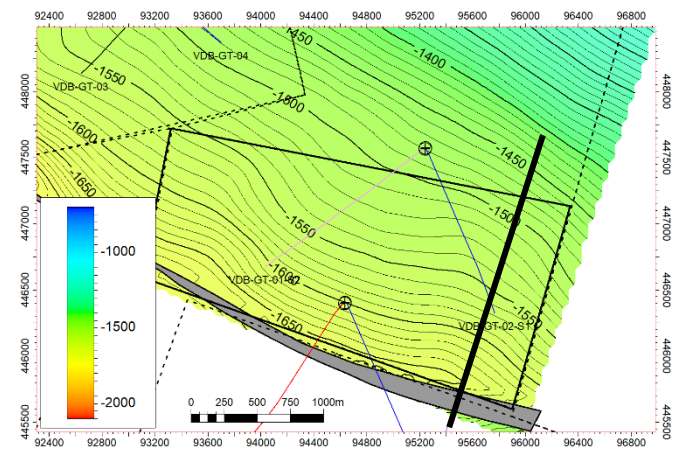
# VDB-GT-02-S1 Berkel reservoir



# VDB-GT-02-S1 Berkel reservoir

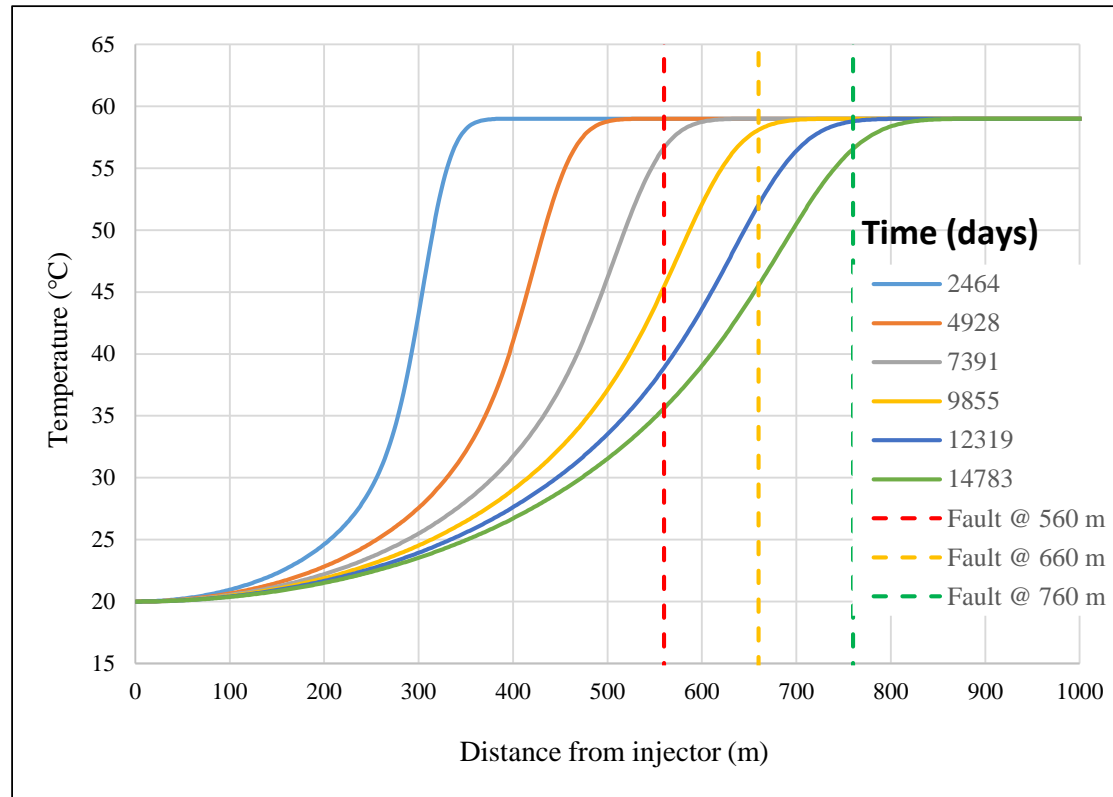


220 m<sup>3</sup>/hr  
from 2022

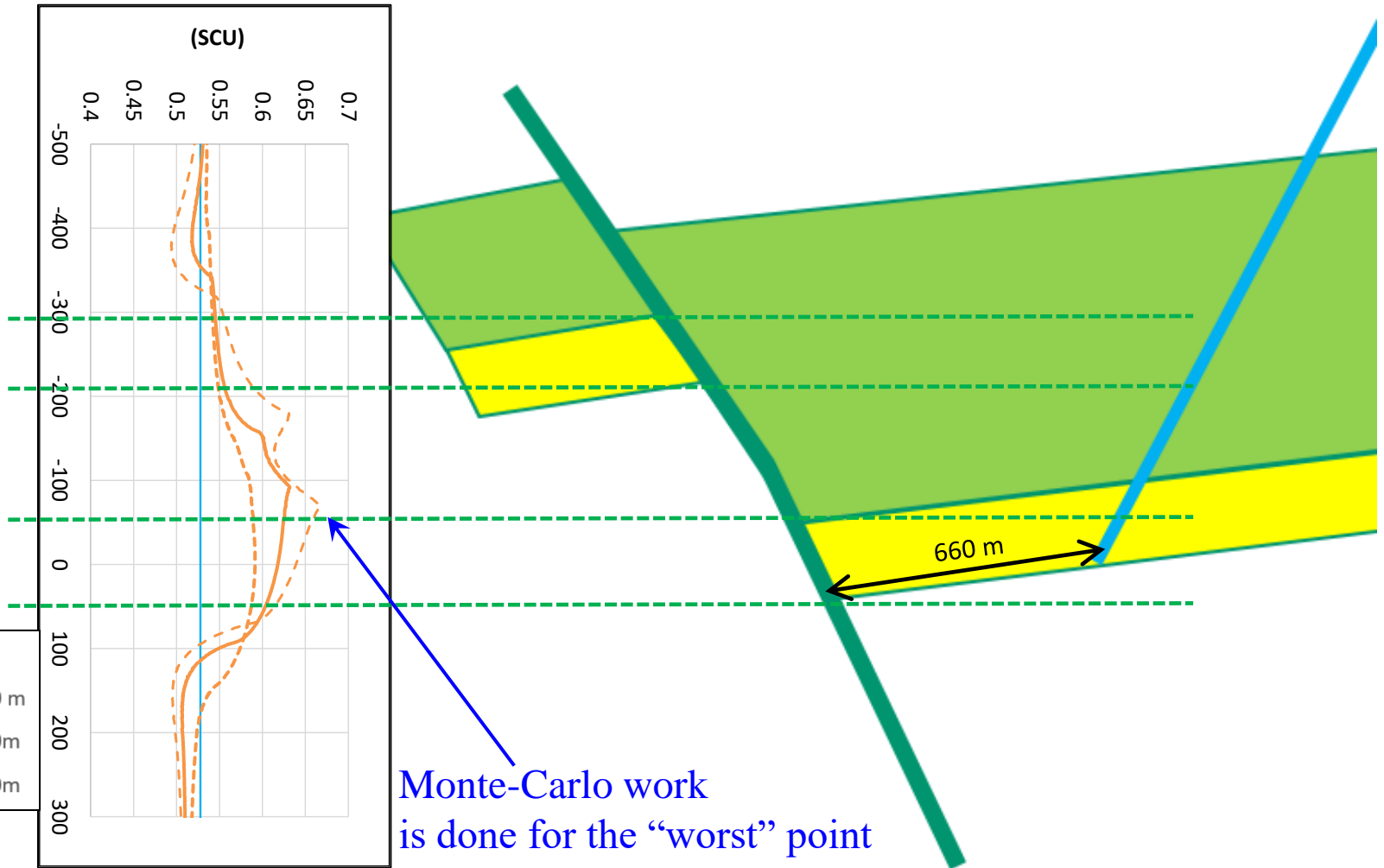


# VDB-GT-02-S1: Temperature profile after 40 yrs @ 220 m<sup>3</sup>/hr

- In order to capture the fact that **injection has already been taking place** in these reservoirs for **± 15 years @ ~150 m<sup>3</sup>/hr**, and to allow for **another operational period of 30 years @ 220 m<sup>3</sup>/hr**, a **total injection period of 40 years @ 220 m<sup>3</sup>/hr** was chosen.
- Temperature front is not sharp but influenced by reservoir diffusion & diffusion from cap/base rock.
- Thermo-elastic stresses at the fault are computed based on lateral and vertical temperature profile of the cooled zone.
- It is conservatively assumed that injected (cold) water that reaches the fault is subsequently displaced into the juxtaposed part of the reservoir on the other side of the fault.

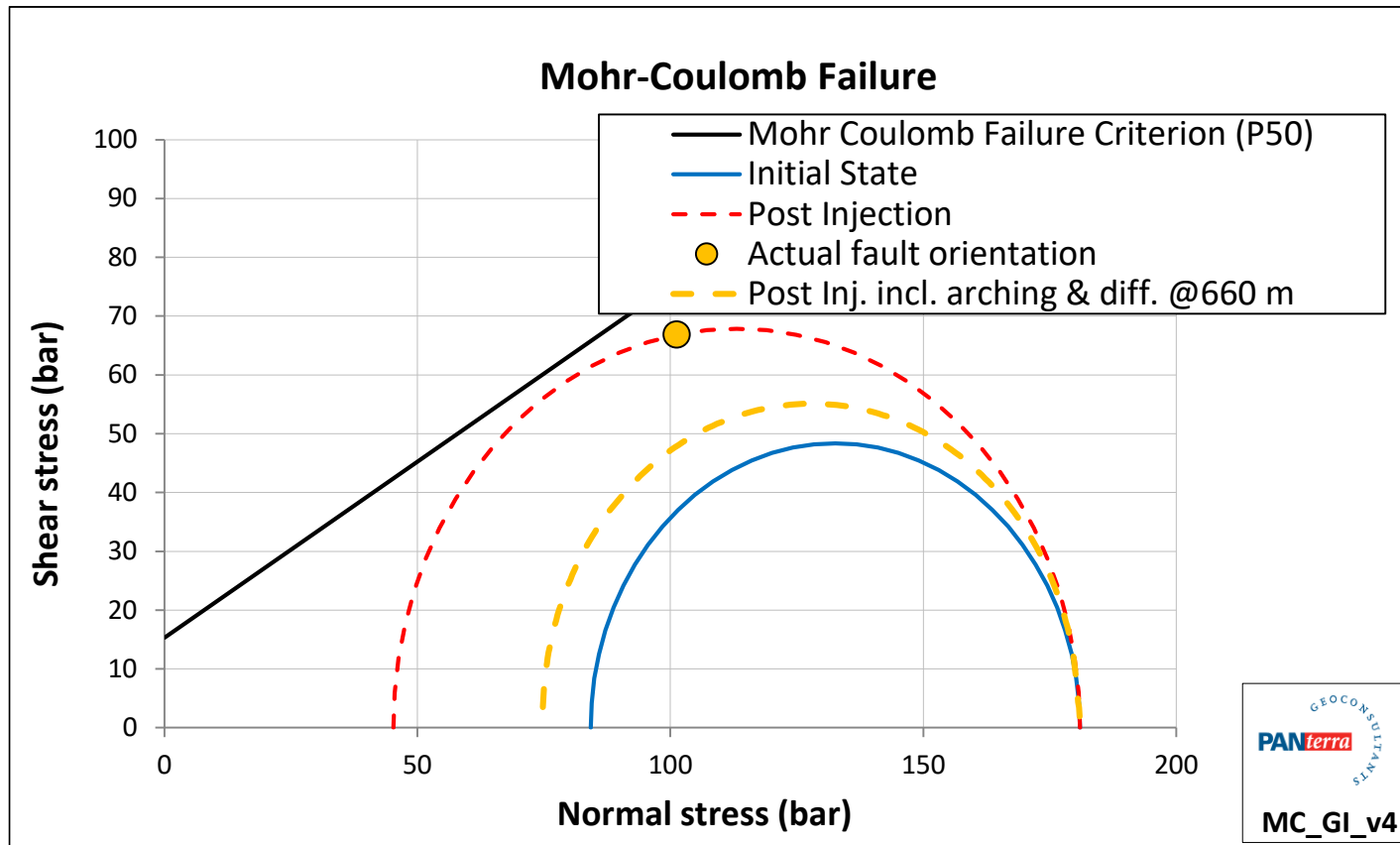


# VDB-GT-02-S1 Berkel reservoir 40 yrs @ 220 m<sup>3</sup>/hr



# VDB GT-02 Berkel 40 yrs @ 220 m<sup>3</sup>/hr

- Base Case & below SCU threshold of 1 (max. SCU of 0.63, see previous slide)
- Varying fault distance over +/- 100 m with respect to base case of 660 m from injector has some impact on SCU (max. SCU between 0.59 and 0.66)
- The combined effect of some arching and (mostly) temperature diffusion in the reservoir results in a modest reduction of the Mohr circle radius



# VDB-GT-02 Berkel 40 yrs @ 220 m<sup>3</sup>/hr

## Probabilistic analysis: Monte Carlo

### Objective:

- Geomechanical parameters can exhibit a large uncertainty
- To visualize & quantify the impact of the uncertainties, a Monte Carlo simulation of Mohr Coulomb is performed

### Input Parameters:

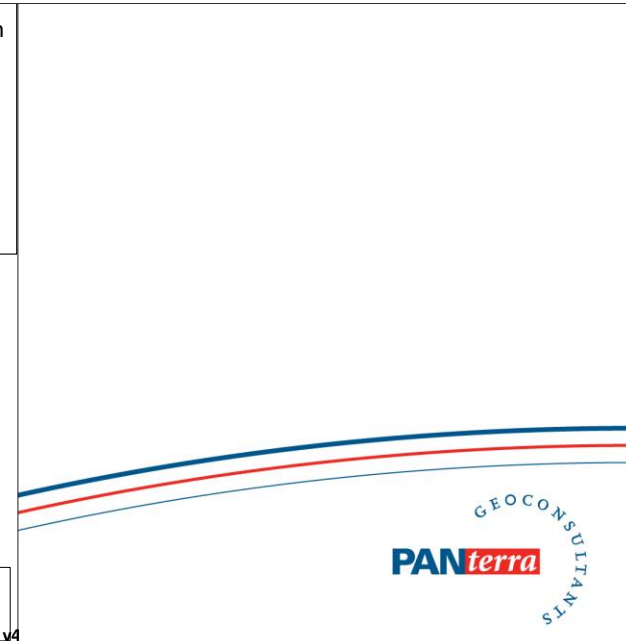
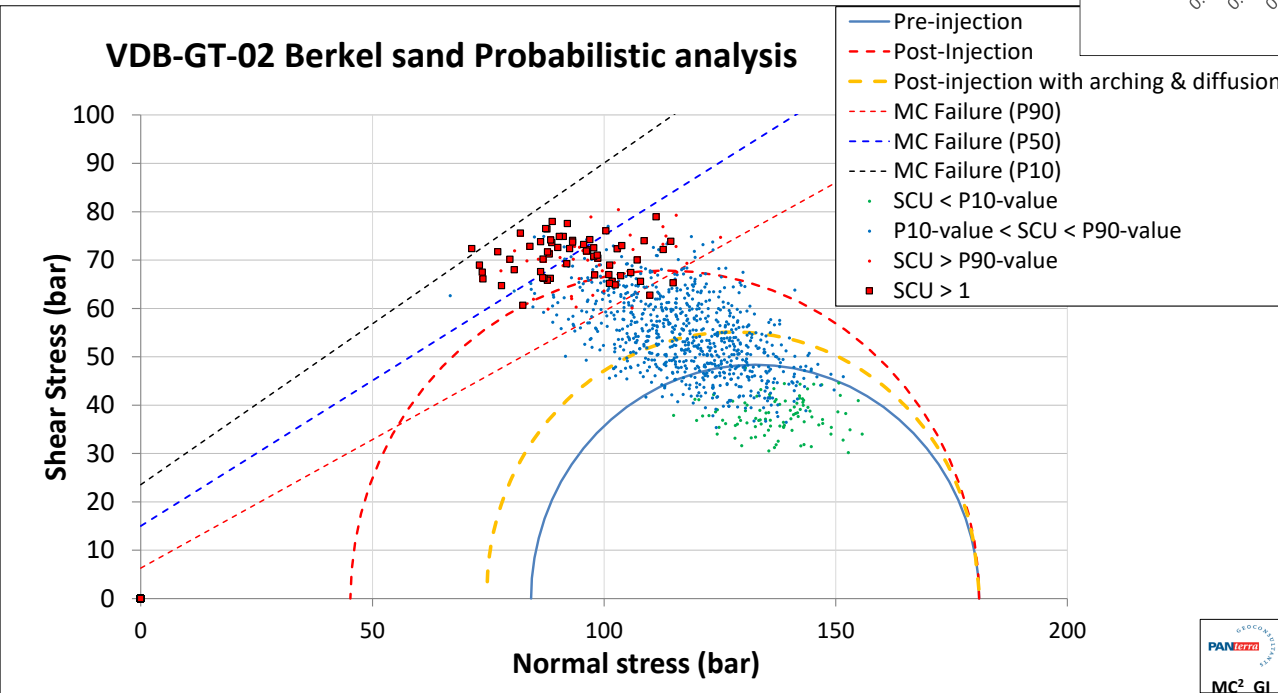
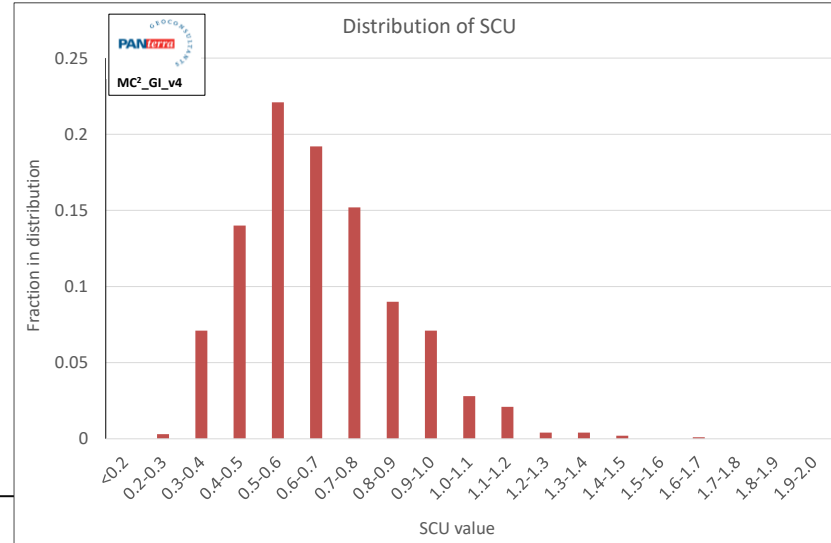
- Reservoir temperature  $59 \pm 3$  °C
- Thermoelastic coefficient based on literature
- Vertical & Horizontal stress gradients based on literature and offset wells
- Fault cohesion from literature 0-15-30 bar
- Friction coefficient from literature 0.48-0.60-0.72
- Dip of the fault: approximately 40-50-60°

	Parameter	Min	Median	Max
Rock Parameters	Reservoir Temperature (°C)	56	59	62
	Thermoelastic coefficient (bar/°C)	0.5	1.0	1.5
	Vertical stress gradient (bar/m)	0.21	0.22	0.23
	Horizontal stress gradient (bar/m)	0.125	0.158	0.189
Fault Parameters	Cohesion (bar)	0	15	30
	Friction coefficient (-)	0.48	0.60	0.72
	Dip (degrees)	40	50	60
	Distance from injector (m)	560	660	760

# VDB GT-02 Berkel 40 yrs @ 220 m<sup>3</sup>/hr

## Probabilistic analysis: Monte Carlo

- 6% cases with SCU > 1 (i.e. above the P90 Mohr-Coulomb line)
- 7% cases with SCU between 0.9 and 1 (for the P90 Mohr-Coulomb failure line)



# Conclusions

- Conservative approach:
  - Assumed that faults are non-sealing.
- In order to capture the fact that injection has already been taking place in these reservoirs @ ~150 m<sup>3</sup>/hr for ± 15 years, and to allow for another operational period of 30 years @ 220 m<sup>3</sup>/hr, a total injection period of 40 years @ 220 m<sup>3</sup>/hr was chosen.
- The nearest fault is located at approximately 660 m from injector VDB-GT-02-S1. This is slightly less than the expected extent of the thermal front after 40 years @ 220 m<sup>3</sup>/hr.
- As a result of the above, the likelihood for fault reactivation is low.
- A Mohr-Coulomb Monte-Carlo simulation shows that the likelihood of fault reactivation after 40 years of injection @ 220 m<sup>3</sup>/hr is close to that for zero injection.

# Additional study

Co-production overburden reservoirs and effects on pressures

# Co-production overburden reservoirs

## Effects of additional injected volumes to reservoir pressure

- In order to assess the effects of the re-injected allochthonous water (i.e. “overburden water”) the origin was determined
  - By studying the casing integrity failures coinciding with known potential reservoirs
  - An **abrupt** and **constant temperature drop** of 6°C is observed from June 2016 till close-in; from **60 °C → 54 °C**
- 3x possible reservoirs identified: Breda, Texel Greensand & Holland Greensand fms
- Due to the constant drop in temperature, the percentage **flow** from the **overburden** reservoir must be **stable**
- A **low / high estimate** of influx estimated required for temperature drop, based on the overburden Fm.
  - Production Berkel/Rijswijk reservoir known
  - Temperature effect of overburden reservoir dependent on the (prevailing) reservoir depth i.e. water temperature
  - Shallowest: **Breda Fm.**; ~14 °C → **0.5 Mm3** influx
  - Deepest: **Holland Greensand Fm.**; ~36 °C → **1.4 Mm3** influx

# Overburden pore volumes determination to quantity influx

- To QC volume range and acquire more a precise value, a reservoir study performed
  - Analysis of (regional) reservoir properties
  - Study of local well thicknesses from the VDB-GT-01/-04
- Aim: estimate of the overburden reservoirs pore volumes
  - High and low estimate based on regional continuity (BTU erosion)
  - (very) limited data available for Breda & Holland Greensand fms
    - Reservoir properties Holland Greensand populated in other fms
- Thicknesses and resulting pore volumes:

	Average thickness (m)	Gross volumes - Low (km3)	Gross volumes - High (km3)	Average (km3)	Depth	Temperature (deg C)
Berkel / Rijswijk	80	2113	4013	3063	1680	60
Holland Greensand	40	566	1390	978	1000	35.71
Texel Greensand	5	31	174	102.5	640	22.86
Breda basal sst	10	172	516	344	400	14.29

# Conclusion

## Negligible effects on both reservoir & overburden pressures

- Co-production assumed, based on ratio overburden volumes
  - 80% of total production estimated from Berkel/Rijswijk reservoir
  - 20% of total production estimated from overburden layers
  - Therefore 20% (2.1 Mm<sup>3</sup>) more injected into than produced from reservoir and 2.1 Mm<sup>3</sup> produced from overburden without any injection
- Pressure **increase** at reservoir level in the order of 1 kPa (**0.01 bar**)
  - By multiplying mismatch volumes, reservoir-volumes & compressibility ( $\sim 10^{-4}$  /bar)
- Pressure **decrease** at overburden level in the order of 3 kPa (**0.03 bar**)
  - By multiplying mismatch volumes, reservoir-volumes & compressibility ( $\sim 10^{-4}$  /bar)
- Therefore **co-production** has a **negligible effect** on both reservoir pressure and overburden pressure
  - a **SHA Lvl 1** risico profile is **sufficient**
- Additional comments:
  - It should be noted that since the observed temperature drop (June 2016) no ground level movement has been observed possibly related to the co-production
  - Any future completions will not have any co-production and purely aim to produce (and inject) from the targeted reservoir